

Corn Distillers' Grains and Other By-Products of Alcohol Production in Blended Foods. II. Sensory, Stability, and Processing Studies[1,2]

G. N. BOOKWALTER, K. WARNER, J. S. WALL, and Y. V. WU, Northern Regional Research Center, Agricultural Research Service, U.S. Department of Agriculture, Peoria, IL 61604; and W. F. KWOLEK, biometrician, North Central Region, stationed at the Northern Regional Research Center, Agricultural Research Service, U.S. Department of Agriculture, Peoria, IL 61604

Cereal Chem. 61(6): 509–513

ABSTRACT

Flavor and storage stability are important factors in the selection of by-products from the fermentation of grain for use in blended foods for the Food for Peace program. In addition to alcohol, fermentation of corn produces corn distillers' grain (CDG) and corn distillers' solubles (CDS), which are usually combined to produce corn distillers' grains with solubles (CDGS). Commercial sources of these products were analyzed for changes in peroxide, free fatty acid, and available lysine during storage at 49°C, to establish product stability. A trained taste panel judged the flavor quality of CDGS as poor and unacceptable. The panel judged products containing 5% or more CDG with a blend of cornmeal, soy flour, and nonfat dry milk solids (NDMS)—known as corn-soy-milk (CSM)—to be significantly lower in flavor quality than CSM alone. Blends containing more than 5% CDG also produced darker-colored products. Corn-protein concentrate (CPC) had good flavor characteristics but could not be used in large amounts in blends because of its lysine deficiency. CDG flavor was improved by water washing and hexane:ethanol azeotrope lipid extraction.

The availability of large amounts of by-products from the fermentation of grain to alcohol has spurred interest in increasing their usage. These materials are rich in protein, and their use in supplementing cereals in food products has been considered. Wall et al (1984) reported that some of these products can be incorporated with other ingredients to yield blended foods suitable for meeting the energy and nutritional requirements for overseas donations in the Food for Peace program. Blended foods for these programs are designed to prevent malnutrition of children in developing areas of the world by providing adequate supplies of protein, calories, and other nutrients. However, they must have suitable flavor, appearance, and shelf-life to ensure widespread acceptance and sustained use. Specifications for the cornmeal, soy flour, nonfat dry milk solids (NDMS) blend known as CSM were issued by USDA's Agricultural Stabilization and Conservation

[1]Presented in part at the 68th annual meeting of the American Association of Cereal Chemists in Kansas City, MO, Oct. 30–Nov. 3, 1983.

[2]The mention of firm names or trade products does not imply that they are endorsed or recommended by the U.S. Department of Agriculture over other firms or similar products not mentioned.

Service (1981), and general requirements for blended foods in the Food for Peace program are described by Bookwalter (1981).

In an associated study, Wall et al (1984) obtained a series of CDG and CDGS from industrial sources; when the grains were analyzed for protein, fiber, fat, and ash content, both were found to be uniformly high in protein (28–30%) and fiber (8–13%) but low in certain essential amino acids, including lysine and tryptophan. The composition of a CPC produced by fermenting degermed and dehulled cornmeal was also established. It was low in fiber and high in protein (60%), but lower in lysine than CDG. Based on 18% protein and a chemical score of 90 (Traver et al 1981), blends were formulated to contain different levels of CDG or CPC with soy flour, 5 or 15% NDMS, and cornmeal, all with 5.5% soybean oil, vitamins, and mineral supplements. The soy flour and NDMS provided sufficient lysine and tryptophan. The blends were fed to rats, and digestibilities and protein efficiency ratios (PER) were determined. Blends containing 5 and 10% CDG had minimally acceptable PER values. The presence of more than 2.5 and 5% CPC in blends containing 5 and 15% NDMS, respectively, reduced PER below acceptable values. The fiber content of blends containing 10% CDG exceeded the maximum tolerated value of 2% (ASCS 1981). However, a method for rendering products suitable for blended foods by reducing fiber content in CDG has been described (Wu and Stringfellow 1982).

Changes in peroxide content and free fatty acids in the lipid fraction during accelerated storage of distillers' by-products, including CDGS, CDG, and CPC, were investigated. The loss of available lysine during storage was examined to establish nutrient retention. The distillers' by-products and blends into which they were incorporated were evaluated for sensory quality and characteristics, and methods to improve flavor and shelf-life were explored. We report the conclusions regarding the suitability of the various distillers' by-products and their levels of incorporation in blended foods.

MATERIALS AND METHODS

Materials

The distillers' by-products were mostly the same as those used in an associated study (Wall et al 1984). Brown-Forman (BF) CDG and BF CDGS were obtained from Brown-Forman Co., Louisville, KY; Archer Daniels Midland (ADM) CDG and CDGS were obtained from Archer Daniels Midland Co., Peoria, IL; and CPC was obtained from Miles Laboratories, Elkhart, IN, and Chemapac, Inc., Woodbury, NY. Miles CPC was similar to the products described by Phillips and Sternberg (1979) but was not extracted with ethyl acetate. Both Miles and Chemapac CPCs were separated from enzymatically converted starch before fermentation, whereas the CDG and CDGS products were obtained after fermentation. BF CDG was ground in an Alpine pin mill twice at 18,000 rpm and Miles CPC once at 14,000 rpm. Both products were passed through an 80-mesh screen.

The effect of processing on flavor was established by obtaining ADM CDG at 60% moisture and subjecting it to various extractions and drying steps. Part of the wet CDG was dried at 90°C in a forced-air oven, part in a large pan-type freeze dryer, and part adjusted to pH 6.9 in 10 vol of water and filtered and dried at 90°C. Part of the dried CDG was extracted by stirring with hexane:ethanol (82:18, v/v).

Previous studies established that the flavor of the CDG varied enormously with its industrial source. For comparison, CDG was prepared in our pilot plant on a laboratory scale, using 20-L fermentors to mash and ferment ground corn according to the procedure of Wall et al (1983). The CDG was removed from the stillage by vacuum filtration on cheesecloth supported by a stainless-steel funnel. This CDG, containing 60% moisture, was further washed with 10 vol of water at 25°C. Part of this water-washed, laboratory-prepared CDG was dried at 90°C in a forced-air oven, and part was freeze-dried.

Degermed cornmeal, partially cooked cornmeal, toasted defatted soy flour, and NDMS were acquired from commercial sources. Blends of various distillers' by-products with degermed cornmeal and the CSM formulation were prepared by standard procedures (Bookwalter 1981).

Analyses

Proximate analyses of blends and their components were obtained by using the American Association of Cereal Chemists (1971) procedures. Peroxide values and free fatty acid content of the fat of the samples were obtained by a method of the American Oil Chemists' Society (1970). The method of Rao et al (1963) was used to measure available lysine.

TABLE I
Composition (As-Is Basis) of Various Corn Distillers' By-Products and Other Ingredients and Their Formulated Blends

Ingredient						Protein ($N \times 6.25$) (%)	Fat (%)	Crude fiber (%)	Ash (%)	Moisture (%)
Processed cornmeal						7.3	0.5	0.4	0.3	9.8
Defatted soy flour						51.4	1.2	3.1	5.8	6.1
Nonfat dry milk						35.8	0.2	···	8.5	3.8
CPC (Miles)[a]						47.7	11.9	4.6	2.4	7.7
CDG (BF)[b]						25.3	12	13.7	1.6	4.6
CDGS (ADM)[c]						28	12	7.2	7.1	13.2
Blends[d]	Corn (%)	Soy (%)	Milk (%)	CDG (%)	CPC (%)					
1	64.7	22	5	···	···	18.3	6.1	1	4.2	8
2	61.7	20	5	5	···	18.1	6.6	1.7	4.3	8
3	58.7	18	5	10	···	17.6	7	2.5	4.2	7.5
4	60.7	16	15	···	···	18.4	6	0.8	4.5	7.5
5	59.7	12	15	5	···	18.1	6.5	1.5	4.5	7.2
6	56.7	10	15	10	···	17.3	7	2.3	5.1	6.9
7	64.2	20	5	···	2.5	18.3	6.6	1.1	4	8
8	63.7	18	5	···	5	18.5	7	1.3	4	8
9	64.7	12	5	···	10	17.1	7.3	1.3	3.7	8.3
10	60.2	14	15	···	2.5	18.2	6.3	0.3	4.6	7.7
11	61.7	10	15	···	5	17.4	6.8	0.4	4.5	7.6
12	60.7	6	15	···	10	18.2	6.8	0.5	4.7	8

[a] Miles Laboratories corn protein concentrate.
[b] Brown-Forman Co. corn distillers' grain.
[c] Archer Daniels Midland Co. corn distillers' grain with solubles.
[d] Each contains 5.5% soy oil, 2.7% minerals, and 0.1% vitamins.

Microbiological Evaluations

Corn distillers' by-products were assayed for microbial content to ensure safety for human consumption. Samples of ADM and BF CDGS, BF CDG, and Miles CPC were submitted to the Daily Milk Laboratory, Peoria, IL, for determination of total bacteria, total mold, *Salmonella*, *Escherichia coli*, and *Staphylococcus* counts. Mean total bacteria and mold counts were 35,000 and 2,000, respectively; *Salmonella*, *E. coli*, and *Staphylococcus* were absent, indicating that the microbiological quality was within safety tolerances.

Sensory Evaluations

Flavor and odor were assessed by a 12-member trained panel, as previously described for soybean products (Warner 1974, 1983). The products were tested as 2% dispersions in charcoal-filtered tap water. Panel members scored overall flavor and odor on a 1–10 scale, with 1 = strong and 10 = bland. The panel also described predominant flavors and rated them on a 0–3 basis for increasing intensity. In tests with CSM, the panel indicated predominant flavors, which were tabulated as percentages of all flavor descriptions reported. Panelists scored overall flavor quality of CSM on a 1–10 scale, with 1 = bad and 10 = excellent. Scores of 6 or more were considered acceptable.

Visual color characteristics of the CDG and CPC products and blends containing them were recorded. Color measurements were also made with a Hunterlab D-25 color difference meter.

Storage Stability

CDG, CDGS, and CPC samples were stored in sealed containers at 49°C for 4 wk. The distillers' by-products were evaluated as 0-time and aged pairs for flavor changes. Levels of peroxides, free fatty acids, and available lysine were tested before and after storage.

RESULTS AND DISCUSSION

Analyses

The compositions of distillers' by-products and blend ingredients are shown in Table I, as reported by Wall et al (1984). Blend formulations and their analyses are also shown. Protein content (as-is basis) of the corn distillers' by-products was 25–48%; fat content, approximately 12%; crude fiber, 4.6–13.7%; ash, 1.6–2.4%; and moisture, 4.6–13.2%. In the blended foods, protein was 17–18%; fat content, 6–7%; and moisture, 7–8%. Fiber content varied with the level of CDG; at 10% CDG, crude fiber was 2.5 and 2.3% with 5 and 15% NDMS, respectively.

The maintenance of stable composition of the distillers' by-products is important when these products are incorporated into blends to ensure good flavor quality and nutritional value. Changes in peroxide value, free fatty acid content, and available lysine are an index of lipid decomposition and protein quality changes resulting from storage and elevated temperatures. As shown in Table II, BF CDG, BF CDGS, and Chemapac CPC had high initial peroxide values. BF CDG and Chemapac CPC peroxide values increased after storage for 4 wk at 49°C, but after 8 wk all peroxide values declined. BF CDG and Chemapac CPC were highest in peroxide values after storage at these conditions. The free fatty acid content of the various products increased during storage. The BF products were lowest, followed by Chemapac, and Miles CPC was highest.

Available lysine content of all distillers' protein by-products was stable during accelerated storage except for Miles CPC (Table II). Because Miles CPC was isolated from the corn mash before fermentation, it contained considerable reducing sugar that reacted with lysine. To maintain nutritional quality of blends by minimizing nonenzymatic browning, CPC must be free of appreciable levels of reducing sugar. Chemapac CPC appears to retain biologically available lysine during storage.

Sensory Evaluations

Color characteristics of various corn distillers' by-products, other ingredients, and their blends are shown in Table III. The colors of the blends changed from normal light yellow to brownish yellow when CDG was added; added CPC caused the blends to become yellower. The brown hue may decrease the visual acceptability of the blended foods. Color measurements taken on a Hunterlab model D-25 color difference meter agreed with visual observations.

Flavor evaluations of the distillers' by-products are shown in Table IV. Wheat flour served as a reference cereal food product and was rated 8. Both CPC samples received acceptable scores of 6 and 7, with the panel describing the flavors as "cereal" and "slightly stale." BF CDG had a lower but acceptable score, whereas both BF CDGS and ADM CDGS had low scores of 3.1 and 2.4, respectively. Both CDGS samples had unacceptably strong flavors that included "sour" and "fermented." The flavor scores for Miles CPC and BF CDG decreased only slightly after storage for 4 wk at 49°C.

For flavor evaluations, 5% CDG products were incorporated into a blend with degermed cornmeal. Scores of the three CDG and cornmeal blends were rated significantly lower ($P<0.01$) than the all-cornmeal sample (Table V). The two CDGS product blends scored lower (5 and 6) than the CDG blend (6.5). Flavor intensity levels shown in Table V indicate that the CDGS blends had undesirable rancid and fermented flavors and were not therefore, incorporated into blended foods.

TABLE II
Storage Stability Characteristics of Corn Distillers' By-Products

Storage Conditions	CDG (BF)[a]	CDGS (BF)[b]	CDGS (ADM)[a]	CPC (Miles)[a]	CPC (Chemapac)[b]
	Peroxide Value Meq./1,000 g Fat				
0 week	30.1	10.9	1.1	9.8	65.4
4 weeks, 49°C	44.7	6.3	1.8	6.7	91.2
8 weeks, 49°C	32	2.7[c]	1.8	5	14[c]
	Free Fatty Acid, Percentage of Oleic				
0 week	5.3	2.1	11.8	21.8	7.6
4 weeks, 49°C	5.3	6	9.5	22.3	11.1
8 weeks, 49°C	5.8	6.7	12	23	9.2
	Available Lysine, Percentage of Protein				
0 week	2.7	2.7	2.8	1.2	1.9
4 weeks, 49°C	2.5	2.4	2.2	0.8	2
8 weeks, 49°C	2.3	2.2	2.3	0.5[c]	1.8

[a]See Table I for definition of terms.
[b]Brown-Forman Co. corn distillers' grain with solubles; Chemapac, Inc., corn protein concentrate.
[c]Significantly different from 0 week value ($P<0.05$).

TABLE III
Color Characteristics of Various Corn Distillers' By-Products, Other Ingredients, and Their Formulated Blends

Base Ingredients	Hunter Lab Color Values[a] L	A	B	Visual Color
Processed cornmeal	+88.43	−0.3	+32.72	Light Yellow
Defatted soy flour	+90.35	−1.01	+13.87	Very light beige
Nonfat dry milk	+96.99	−3.45	+13.29	Creamy white
CPC (Miles)[b]	+79.57	+1.2	+33.32	Dark yellow
CDG (BF)[b]	+61.6	+3.43	+24.03	Light brown
Blends[b]				
1	+84.28	−0.32	+27.44	Light yellow
2	+79.96	+0.21	+26.2	Slightly darker yellow[c]
3	+77	+0.7	+25.4	Brownish yellow[d]
7	+83.64	−0.11	+28.27	Slightly yellower
8	+82.77	+0.11	+29.47	Darker yellow[c]
9	+81.19	+0.47	+31.75	Dark yellow[d]
4	+85.59	−0.59	+26.76	Light yellow
5	+80.67	−0.1	+26.19	Slightly darker yellow[c]
6	+76.97	+0.67	+25.59	Brownish yellow[d]
10	+84.45	−0.28	+28.22	Slightly yellower[c]
11	+83.52	−0.09	+30.13	Darker yellow[c]
12	+81.88	−0.31	+32.84	Dark yellow[d]

[a]Hunter color values = L, lightness; A, +red, −green; B, +yellow, −blue.
[b]See Table I for definition of terms and formula compositions.
[c]Slightly different cast than control (Formulations 1 or 4).
[d]Noticeably different cast than control.

The taste panel evaluated cooked gruels containing 0, 2.5, 5, 7.5, and 10% CDG. Overall flavor quality and flavor descriptions are shown in Table VI. Flavor descriptions are expressed as the percentage of testers reporting a particular flavor. The control CSM received a flavor score of 8 (good quality) on two separate trials. Blends containing 5, 7.5, and 10% CDG received scores of 6.7, 6.5, and 6.4, respectively, which were significantly lower ($P < 0.05$) than the control. The addition of 2.5% CDG resulted in a reduced score of 7.2, which was within the range of flavor variability for control CSM. At the 5 and 10% CDG levels in blends, 30% of the panelists reported fermented flavors and 65% reported other off-flavors. Based on these flavor scores, only the 2.5% CDG addition was considered suitable for CSM-type blended foods.

Table VII shows results of water washing, pH adjustment, and hexane:alcohol azeotrope extraction, which were used to improve the flavor of CDG for use in blended foods. The CDG was washed with 10 vol of water, because residual solubles were previously established as a source of undesirable flavor. The initial CDG sample, dried at 90° C, had a low flavor score of 4, with high levels of musty, bitter, astringent, and fermented flavor components.

TABLE IV
Flavor Scores for Corn Distillers' Grains By-Products After Storage[a]

Storage	Wheat Flour	CPC (Miles)[b]	CPC (Chemapac)	CDG (BF)	CDGS (BF)	CDGS (ADM)
0 weeks	8 (cereal)	7 (cereal, "off")	6 (cereal, stale, toasted)	5.9 (cereal, stale, fermented)	3.1 (sour, astringent bitter, fermented)	2.4 (sour, bitter, fermented, salt, stale)
4 weeks, 49° C	Not tested	6.8	Not tested	5.7	Not tested	Not tested

[a]Tested as 2% dispersions in carbon-filtered tap water.
[b]See Table I for definition of terms.

TABLE V
Flavor Scores and Descriptions for Cornmeal Blends with Corn Distillers' Grain[a]

Description	100% Cornmeal	95% Cornmeal/ 5% CDG (BF)[b]	95% Cornmeal/ 5% CDGS (BF)	95% Cornmeal/ 5% CDGS (ADM)
Scores[c]	8	6.5	6	5
Cereal/grain	1.2	1.3	1.1	1.1
Musty/stale	···	0.4	0.6	0.3
Bitter	···	0.3	0.3	0.6
Fermented	···	0.4	0.8	0.8
Astringent	···	0.3	···	···
Salty	···	···	···	0.3
Other "off" flavors	···	0.5 (metallic, meaty)	1 (sulfur, rancid, burnt, medicinal)	0.9 (oxidized, rotten, paste, feed)

[a]Tested as cooked gruels.
[b]See Table I for definition of terms.
[c]All samples rated significantly lower ($P < 0.01$) than cornmeal.

TABLE VI
Flavor Scores and Descriptions for Corn-Soy-Milk (CSM) Blends Containing Various Levels of Corn Distillers' Grain (CDG)[a]

Sensory Evaluation	Percentage of CDG in CSM Blends 0	2.5	5	7.5	10
Trial A					
Description[b]					
Cereal/corn	100%		80%	100%	90%
Fermented	0%		20%	20%	30%
Total "off" flavors	45%		60%	70%	80%
Flavor scores[c]	8		6.5	6.5	6.4
Trial B					
Description[b]					
Cereal/corn	100%	100%	100%	100%	
Fermented	0%	20%	40%	40%	
Total "off" flavors	30%	40%	65%	70%	
Flavor scores[c]	8	7.2	6.8	6.5	

[a]Brown-Forman Co. corn distillers' grain.
[b]Based on percentage of testers giving response.
[c]Quality scale of 1–10, with 10 = excellent and 1 = bad. CSM containing 5, 7.5, and 10% CDG rated significantly lower ($P < 0.05$) than CSM with no CDG.

TABLE VII
Flavor Scores and Descriptions for Corn Wet Distillers' Grains (CDG) Processed by Different Procedures

Sample	Flavor[b] Score	Flavor Intensity Values[a] Cereal/ Grain	Toasted	Musty/ Stale	Bitter	Astringent	Fermented
Industrially Produced[c]							
CDG, dried 90° C	4 D	1.1	0.5	0.3	0.9	1.1	2.3
CDG, freeze-dried	4.1 D	0.9	0.3	0.2	0.8	1.1	2.1
CDG, H_2O washed (10:1) at 60° C, dried at 90° C	5.4 E	1.3	0.4	0.2	0.4	0.4	1.9
CDG, pH adjusted to 6.9, filtered, dried at 90° C	5.7 E,F	1.1	0.6	0.1	0.4	0.4	1.4
CDG, dried at 90° C defatted with hexane:ethanol azeotrope	6.2 F	1	0.1	0.1	0.1	0.5	1.1
Laboratory Prepared[c]							
CDG, H_2O washed (10:1) at 25° C, dried at 90° C	6.3 F	0.8	···	0.5	0.4	···	1.3
CDG, H_2O washed (10:1) at 25° C, freeze-dried	6.3 F	0.6	···	0.4	0.3	···	1.3

[a]Based on 0–3 intensity scale, with 0 = none and 3 = strong.
[b]Based on 1–10 scale, with 10 = bland and 1 = strong. Flavor scores with no common letter (D, E, or F) differ significantly ($P < 0.05$).
[c]Moisture reduction from 60% to 5% by various treatments.

After water washing, the score improved to 5.4 and bitter and astringent flavors were greatly reduced. Because off-flavor components of the CDG might be acidic in nature, their removal would be more effective at neutral pH. For this reason, the pH of the CDG was adjusted to 6.9 before washing. The resulting product, after drying, had a flavor rating of 5.7. The fermented flavor component was markedly reduced by this treatment. Another possible source of off-flavor was deterioration of lipids during fermentation and drying. Extraction of lipids with hexane:alcohol azeotrope improved the flavor score appreciably, to 6.2, and reduced the musty, bitter, astringent, and fermented flavor components. To ensure that some of the off-flavor was not due to the drying process, part of the CDG was freeze-dried. The freeze-dried and oven-dried products showed no difference in flavor score. Water-washed, pH-adjusted, and solvent-extracted CDG samples were also tasted after freeze-drying, and no flavor differences were found.

Both oven- and freeze-dried laboratory-prepared, water-washed CDG samples had flavor scores of 6.3 (Table VII). The taste panel reported little astringent or toasted flavor in the laboratory-prepared CDG samples. These results demonstrate that method of preparation and handling of the CDG can result in significant improvements in their flavor quality. Further process studies are underway to determine the most cost-effective method of producing CDG that can serve as an acceptable component of blended foods.

CONCLUSIONS

Poor flavor of CDGS and lysine deficiency of CPC render these products unsuitable for use in blended food mixtures. However, 2.5% commercially available CDG could be used in blended foods without having an adverse quality effect. The flavor of CDG can be greatly improved by either water washing or defatting with hexane:ethanol azeotrope.

LITERATURE CITED

AGRICULTURAL STABILIZATION AND CONSERVATION SERVICE, USDA. 1981. Purchase of corn-soya-milk instant corn-soya-milk for use in export programs, CSSM-1. Kansas City, MO.

AMERICAN ASSOCIATION OF CEREAL CHEMISTS. 1971. Approved Methods of the American Association of Cereal Chemists. The Association, St. Paul, MN.

AMERICAN OIL CHEMISTS' SOCIETY. 1970. Official Methods, 3rd ed., American Oil Chemists' Society, Chicago, IL.

BOOKWALTER, G. N. 1981. Requirements for foods containing soy protein in the Food for Peace program. J. Am. Oil Chem. Soc. 58:455.

PHILLIPS, R. D., and STERNBERG, M. 1979. Corn protein concentrate:functional and nutritional properties. J. Food Sci. 44:1,152.

RAO, S. R., CARTER, F. L., and FRAMPTON, B. L. 1963. Determination of available lysine in oilseed meals proteins. Anal. Chem. 35:1,927.

TRAVER, L. E., BOOKWALTER, G. N., and KWOLEK, W. F. 1981. A computer-based graphical method for evaluating protein quality of food blends relative to cost. Food Technol. 35:72.

WALL, J. S., BOTHAST, R. J., LAGODA, A. A., SEXSON, K. R., and WU, Y. V. 1983. Effect of recycling distillers' solubles on alcohol and feed production from corn fermentation. J. Agric. Food Chem. 31:770.

WALL, J. S., WU, Y. V., KWOLEK, W. F., BOOKWALTER, G. N., and WARNER, K. 1984. Corn distillers' grains and other by-products of alcohol production in blended foods. I. Composition and nutritional studies. Cereal Chem. 61:504–509.

WARNER, K., ERNST, J. O., BOUNDY, B. K., and EVANS, C. D. 1974. Computer handling of taste panel data. Food Technol. 28:42.

WARNER, K., MOUNTS, T. L., RACKIS, J. J., and WOLF, W. J. 1983. Sensory characteristics and gas chromatographic profiles of soybean protein products. Cereal Chem. 60:102.

WU, Y. V., and STRINGFELLOW, A. C. 1982. Corn distillers' dried grains with solubles and corn distillers' dried grains: dry fractionation and composition. J. Food Sci. 47:1,155.

[Received March 19, 1984. Revision received June 25, 1984. Accepted July 2, 1984.]